Oration for Ms Margaret H. Hamilton

by the sponsor Prof. Núria Castell Ariño
Universitat Politècnica de Catalunya · BarcelonaTech. 18th October 2018

Distinguished rector of the Universitat Politècnica de Catalunya · BarcelonaTech, distinguished members of the University Senate and Board of Trustees, authorities and representatives of institutions and companies, professors, students, administrative staff, family and friends, and dear Ms Margaret H. Hamilton.

It is a great pleasure to be here today at this solemn ceremony to welcome to the University Senate a new doctor *honoris causa* of the Universitat Politècnica de Catalunya (UPC), pursuant to the Governing Council decision of 23 May 2017, sponsored by the Facultat d'Informàtica de Barcelona (FIB), of which I am proud to have been the dean. Margaret H. Hamilton's nomination was supported by UPC departments and schools and several internationally well-known experts in software engineering and computing history.

Margaret H. Hamilton has a long list of accomplishments. She is a computer scientist, a systems engineer, and a business owner and entrepreneur. She is also known as the woman who got man to the Moon. During her long research and professional career, her research interests have included systems and software with a preventative paradigm, formal theory, ultra-reliable systems, error detection and recovery, modelling and programming languages, reusability, correctness by built-in language properties, man-machine interfaces, open architectures, seamless integration, operating systems, automated life-cycle environments, software development productivity, systems design and software development within an asynchronous, distributed system-of-systems environment, and software life-cycle management.

Hamilton began working on several software projects at the Massachusetts Institute of Technology (MIT) at Boston, learning by herself about systems and software. From there she got a position at NASA as the lead developer for the Apollo on-board flight software. During the early days of Apollo, she realized that software was not taken as seriously as other engineering disciplines within and outside computing. Hamilton and her team created methods, standards, rules and tools for developing the flight software. To give legitimacy to the process of building software she came up with the idea of naming the discipline "software engineering".

The 2017-2018 academic year has been a very special year for the FIB. It was the celebration of its 40th anniversary. Since 1977 our

school offers top-quality university education and excellence in the area of computing engineering that responds to the needs of the social and economic environment. Software engineering and programming with high-quality criteria are basic elements of education at the FIB, and constitute the working domain of several UPC research groups. Because of this, we sponsored this candidature and today we are proud to welcome Ms Margaret H. Hamilton, a pioneer in computer science history, to the UPC Senate.

Furthermore, the software engineering community celebrates the 50th anniversary of the discipline this year. Around the world several institutions and conferences commemorate this fact. The present award ceremony is our recognition of Ms Hamilton's contributions to this discipline, the discipline which she named.

In addition, next year the world will commemorate the 50th anniversary of the first landing by man on the Moon. The contributions of Ms Hamilton and her team were crucial to Apollo 11's successful landing on the Moon on 20 July 1969. For that historical accomplishment, the UPC's aeronautics schools, as well as the FIB, are proud to welcome her as a new University Senate member.

Certainly, the accomplishments of Ms Margaret H. Hamilton have been key in both areas: computing engineering and aeronautical engineering.

Margaret Heafield Hamilton, born on 17 August 1936, in Paoli, Indiana, studied mathematics at the University of Michigan in 1954 and subsequently earned a B.A. in mathematics with a minor in philosophy from Earlham College in 1958. She moved to Boston, Massachusetts, where her husband went to Brandeis for a master's degree in chemistry followed by a law degree at Harvard Law School. During this time, Hamilton worked to support her family.

Hamilton's plan was to pursue graduate study in abstract mathematics at Brandeis University as soon as she and her husband took turns finishing their studies at their respective schools. She cites a female math professor as a mentor and major influence on her desire to continue in the study of abstract mathematics. She had other inspirations outside the technological world, including her father, philosopher and poet, and her grandfather, a school headmaster and Quaker minister. She says both her father and grandfather inspired her to minor in philosophy.

To prepare for further studies in abstract math at Brandeis University, in 1959 she took an interim position at MIT to develop software for predicting weather on MIT's LGP-30 computer, which she did in hexadecimal, and MIT's PDP-1 computer, for Professor Edward Norton Lorenz in the meteorology department.

Margaret H. Hamilton then developed software for the Semi-Automatic Ground Environment (SAGE) air defense system at Lincoln Laboratories. As soon as she heard MIT was looking for people to build software for sending man to the Moon, she joined NASA/MIT's project to build Apollo's on-board flight software for the manned missions. At that early time, computer science and software engineering were not yet disciplines; instead, programmers had to learn on the job with hands-on experience.

From 1961 to 1963, she worked on the SAGE Project at Lincoln Lab, where she was one of the programmers who wrote software for the first AN/FSQ-7 computer (the XD-1), to search for unfriendly aircraft; she also wrote software for the Air Force Cambridge Research Laboratories.

The SAGE Project was an extension of Project Whirlwind, started by MIT, to create a computer system that could predict weather systems and track their movements through simulators. SAGE was soon developed for military use in anti-aircraft air defense from potential Soviet attacks during the Cold War. It

was her efforts on this project that made her a candidate for the position at NASA as the lead developer for the Apollo on-board flight software.

Hamilton then joined the Charles Stark Draper Laboratory at MIT, where she began by working on flight software for the Apollo unmanned space missions. Shortly thereafter, Hamilton was put in charge of the whole team that developed the Apollo on-board flight software for the manned missions and the subsequent Skylab missions. This included the software developed on the Apollo Guidance Computer for the Command Module (CM), the Lunar Module (LM), and the interfaces ("glue") between and among all the mission phases. It also included the systems software, which was shared by and resided within both the CM and the LM. The system software included the error detection and recovery software such as the restarts and the Priority Displays, which Hamilton designed and developed. No software errors surfaced during actual flights.

She worked to gain hands-on experience during a time when computer science courses were very rare and software engineering courses did not exist.

The Apollo 11 mission was special. No human had ever landed on the Moon before. Everything was going perfectly until something totally unexpected happened, precisely at the critical moment just before landing. Three minutes before the Lunar lander reached the Moon's surface, the Apollo Guidance Computer became overloaded.

Program alarms indicated "executive overflows", meaning the guidance computer could not complete all of its tasks in real time and had to postpone some of them.

However, thanks to the alarm and priority tasks systems developed by Hamilton's team, the situation was managed, and the Priority Displays gave the astronauts the choice to land or not to land. And they landed. The Apollo 11's crew became the first humans to walk on the Moon, and the Hamilton team's software became the first software to run on the Moon.

Dr. Paul Curto, senior technologist who nominated Margaret Hamilton for a NASA Space Act Award, called Hamilton's work "the foundation for ultra-reliable software design".

Hamilton's software engineering group worked on several projects after Apollo.

In 1976, Margaret H. Hamilton co-founded a company called Higher Order Software. She was the CEO from 1976 through 1984. Their aim was to further develop ideas about error prevention and fault tolerance emerging from her experience at MIT.

They created a product called USE.IT, based on the Higher Order Software (HOS) methodology developed at MIT. It was successfully used in numerous government projects. One notable project was to formalize and implement the first computable IDEF (Integration DEFinition), C-IDEF for the Air Force, based on HOS as its formal foundation.

A detailed analysis of the HOS theory and the AXES language was used by Harel to develop a derived language for a more modern form of structured programming derived from HOS called the And/Or programming language from the viewpoint of and/or subgoals.

Harel goes on to show how HOS and his derived And/Or programming language relate to mathematical logic, game theory and artificial intelligence. Others have used HOS to formalize the semantics of linguistic quantifiers, and to formalize the design of reliable real-time embedded systems.

Margaret H. Hamilton left the company, HOS, in 1985. At this time, she continued her pursuit of error-free software.

In March 1986, she became the founder and CEO of Hamilton Technologies, Inc. (HTI) in Cambridge, Massachusetts. The company was developed around the Universal Systems Language (USL) and its associated automated environment, the 001 Tool Suite, based on her paradigm of Development Before The Fact (DBTF) for systems design and software development. HTI and its customers developed many applications using USL.

Margaret H. Hamilton coined the term "software engineering"- during her days working on the Apollo missions. In 50 years, this discipline has gained the same respect as any other engineering discipline.

From the very beginning, as a pioneer software engineer, she was very concerned about possible errors and unexpected situations. During her long research and professional career, she has developed criteria, methodologies, languages, and tools for ultra-reliable systems. She has published over 130 papers, proceedings, and reports about the 60 projects and 6 major programs in which she has been involved.

Google engineers credit Margaret H. Hamilton as the first Site Reliability Engineer (SRE).

To mention some of the honors and awards already presented to her: on 22 November 2016, Margaret H. Hamilton was awarded the Presidential Medal of Freedom by U.S. President Barack Obama for her work leading the development of the on-board flight software for NASA's Apollo Moon missions. This is the highest civilian honor in the United States.

In 1986, she received the Ada Lovelace Award by the Association for Women in Computing. In 2003, she was given the NASA Exceptional Space Act Award for scientific and technical contributions. The award included $37,200, the largest amount awarded to any individual in NASA's history. In 2009, she received the Outstanding Alumni Award from Earlham College.

On 28 April 2017, she received the Computer History Museum Fellow Award that honors exceptional men and women whose ideas have changed the world.

In 2017, a "Women of NASA" LEGO set went on sale featuring (among other things) mini-figurines of Margaret Hamilton, Mae Jemison, Sally Ride, and Nancy Grace Roman.

Margaret H. Hamilton's contributions have played an important role in getting humans to the Moon, in giving legitimacy to software engineering, in giving importance to software reliability, and in helping to open the door for more women to enter the computing field.

Thanks, Margaret, for all your contributions!